The LHCb VELO Upgrade

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On Behalf of the LHCb VELO Upgrade
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LHCb Detector

Heavy Flavour Experiment

Precise vertex reconstruction

Tracking and momentum resolution

Particle identification capabilities

$2 < \eta < 5$

By the end of Run II many analysis become statistically limited.

Increasing Luminosity in order to achieve $50\text{fb}^{-1}$ in Run III.

$4 \times 10^{32} \text{ cm}^{-2}\text{s}^{-1} \rightarrow 20 \times 10^{32} \text{cm}^{-2}\text{s}^{-1}$

Upgrade Trigger implemented on software only.

Readout: 1 MHz $\rightarrow$ 40 MHz
LHCb Detector Upgrade

- New Upstream Silicon Tracker
- New Scintillating Fibre Tracker
- Removal of M1, PS/SPD
- New Upstream Silicon Tracker
- New optics and MaPMTs
- New MaPMTs
- This talk
The VELO Upgrade

- Full 40 MHz readout, Luminosity 5x Higher.
- Change from Silicon Microstrips to Hybrid Pixel Detector.
- Data Bandwidth of 20 Gbit/s for central ASICS.
- Microchannel CO2 cooling, sensor temperature <-20°C
VELO Upgrade

Expected fluence in the most irradiated regions up to $1.5 \times 10^{14}$ $1\text{MeV n}_{eq}/\text{cm}^2$ per fb$^{-1}$

Radiation flux follows $r^{-2.3}$ shape.

Proximity to interaction region: 5.1mm

Total Integrated Luminosity: 50fb$^{-1}$!
VELO Upgrade Module

Module PRR to happen soon. Validation of DAQ, Cooling, Mechanics.

4 Sensors per module
52 modules

Develop procedure and tests for production environment.
VELO Upgrade Module

Silicon μChannel Substrate

VeloPix ASIC

Silicon Sensors

Kapton Hybrids

~43 mm

~14 mm

CO₂ Connector

Data Connection
Mechanics

VELO Hood in production.

RF Foil separates the LHC beam from the VELO secondary Vacuum.

New RF Foil, thinned down to 250um.
μ-Channel Cooling

Silicon substrate built with micro channels that will carry CO₂ for evaporative cooling.

System designed to cool a load of up to 30W from each module.
DAQ

Credit Card PC

Altera FPGA

LHCb Readout Board v1

Control
Data
Power

Vacuum

VelOpIx Hybrid

DCDC

VTTx

SCA

GBTx

VTRx

GBTx

Control Hybrid

Optical

14th Pisa Meeting on Advanced Detectors 2018
DAQ

VeloPix hybrids being tested with LHCb Upgrade Readout boards.

Firmware integrated pre-existing software, most necessary procedures already in place.
VeloPix

Data driven, binary readout, 25 ns timestamping.

Design based on the Timepix3 ASIC.

65k pixels/ASIC
55\(\mu\)m x 55\(\mu\)m pixels
Triggerless readout

Optimised for high speed readout.

Peak Rate: 800 Mhits/s/ASIC
Max ASIC Bandwidth: 20.48 Gb/s

SEU Tolerance built in.
Radiation Hard up to 400 MRad
VeloPix Hybrid

Equalisation provides uniform ASIC operation.

Radioactive source measurements allow double check of single pixel response.
Charge Collection

Max Operational Bias Voltage: 1000V

Minimum collected charge per MIP: 6000e-

The sensors must be able to operate under these conditions up to $8 \times 10^{15}$ 1MeV $n_{eq} \text{cm}^{-2}$
Efficiency studied using Timepix3 Telescope in SPS.

Pixel corner efficiency $>99\%$ @ 1000V after VELO lifetime fluence.

Using 39 $\mu$m p-type implants.
What about Sensor HV Tolerance?

Maybe we can ground the sensor through the ASIC!

Thanks to Michael Moll, for the use of probe setup.
Probe Card Jig

How to test each sensor/ASIC for bump bond quality before mounting them to modules?

Probe Card

Stencil

Vacuum Chuck

Flat Support Disk

Probe Station Vacuum Chuck

40μm precision
Bell Jar Jig

Spring loaded probe needles keep small pressure on sensors.

Dowels stop needles before end of spring compression.
Summary

- Microchannel cooling is the cooling solution to be used by the VELO Upgrade.
- DAQ structure for the VeloPix control and readout are now in place.
- VELO Module Production should start June-July.
- Bump Bonding of Sensors to VeloPix ASICS currently on pre-production.
- First data taking after LS2 in 2021!
Thank you!
Backup
LHCb Detector Upgrade

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Fluence after 50 fb$^{-1}$

Tip of current VELO

Outer radius of current VELO
QA

- Check the flatness of the surface using the white light interferometer.

Overall height variation of 30 μm over the whole surface.
Cooling

Fluidic connector
Solder foil
Metallization on the silicon substrate

More details on my Poster!
Charge Collection and Depletion Depth

Determined using Grazing Angle Technique.

DUT clusters associated with a track if within a 10 ns window.

Correction for Timewalk effect is applied using charge collection time of tracks passing wishing 20μm of implants.
Charge Collection and Depletion Depth

Neutron Uniformly Irradiated to Full Fluence
Cluster Sizes Distributions

Non-Irradiated Micron n-on-p

Post Irradiation Micron n-on-p